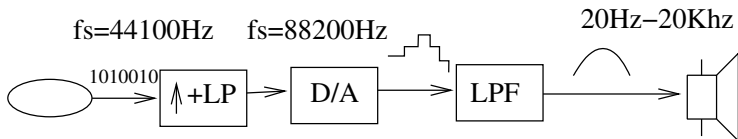
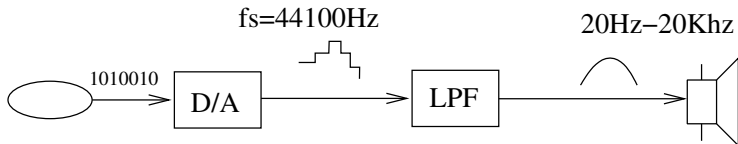


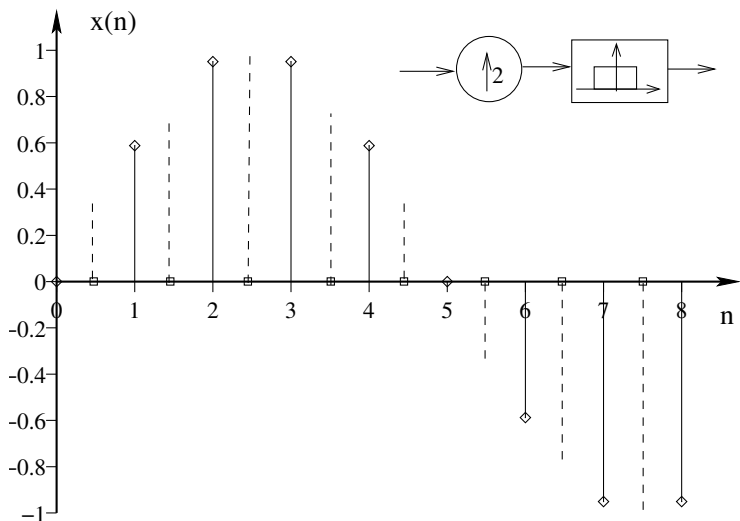
# EDISP: Advanced Techniques

Jacek Misiurewicz

June 15, 2016

- ▶ CD sampling frequency: 44100 Hz
- ▶ Nyquist limit: 22050 Hz
- ▶ Hi-Fi audio: up to 20000 Hz
- ▶ → Analog reconstruction filter problem

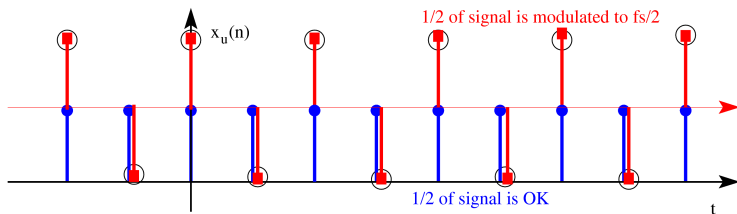




- ▶ Adding points (*upsampling*)
- ▶ Finding values (*interpolation*) – LP filtering

# Upsampling

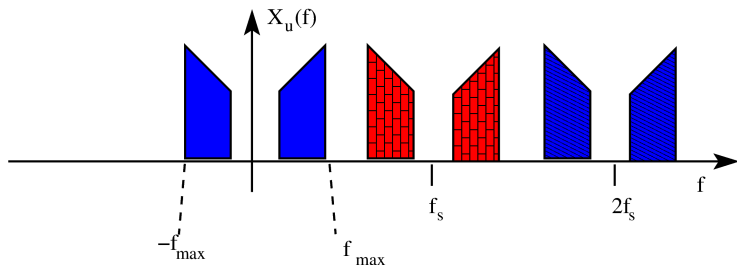
with zeroed samples



so upsampling is equivalent to increasing of sampling frequency and creating additional “alias” at **new**  $\pi$ , extending from  $\pi/2$  to  $3\pi/2$

# Upsampling

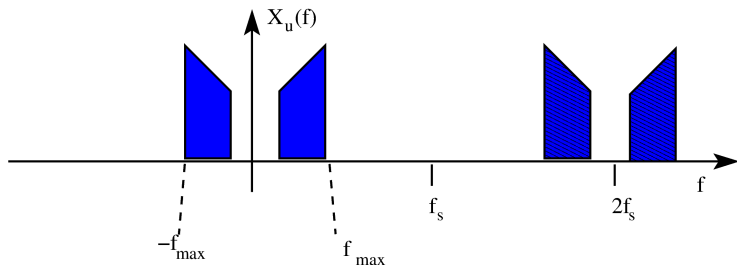
spectral view



We want to remove the “alias” at **new**  $f_s/2$   $\rightarrow$  LowPass filter

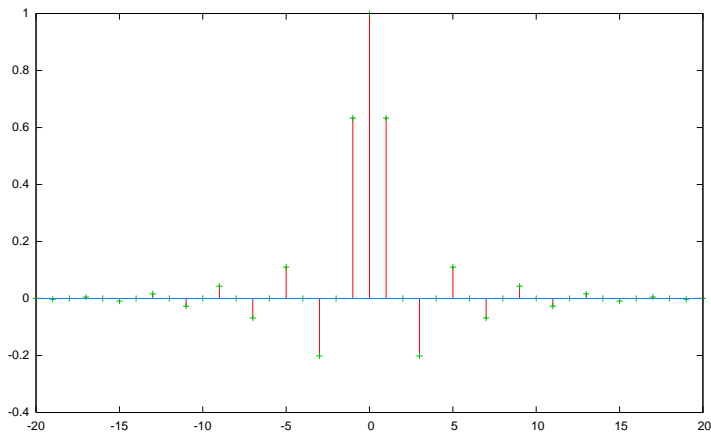
# Upsampling

spectral view



We want to remove the “alias” at **new**  $f_s/2$   $\rightarrow$  LowPass filter

# Interpolating filter (LowPass with $\theta_b = \pi/2$ )



Note *zero* coefficients at even  $n$  positions!

## Do it with FFT

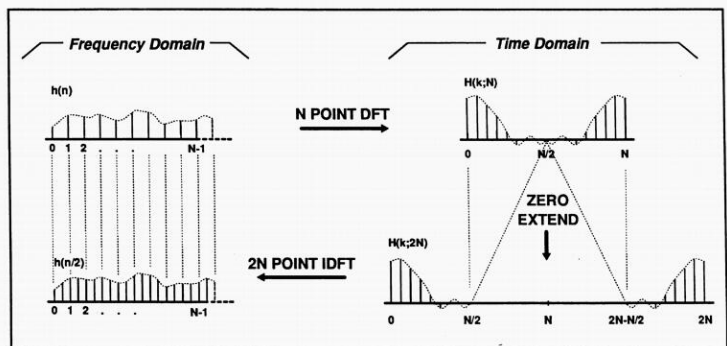
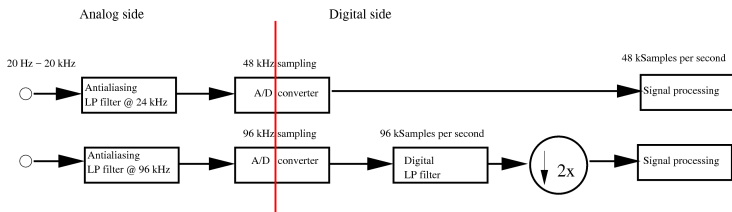


Figure 1. Band-Limited Interpolation with Zero-Extended Spectra

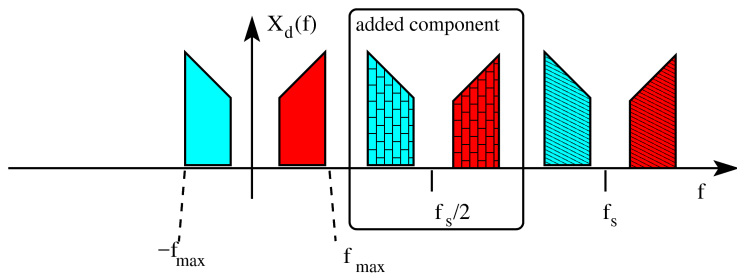


# Oversampling A/D idea



# Downsampling

spectral view

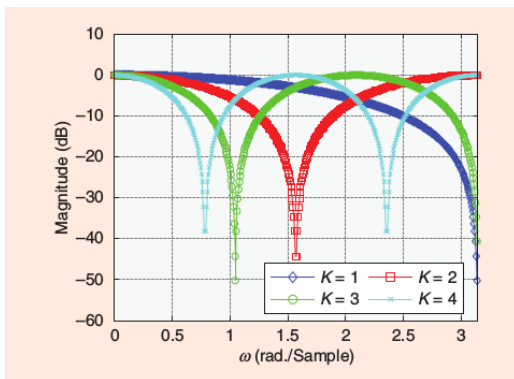


We want to remove the “alias” at **new**  $f_s$  (old  $f_s/2$ )  
 → LowPass filter again...

# LP filter with tricks

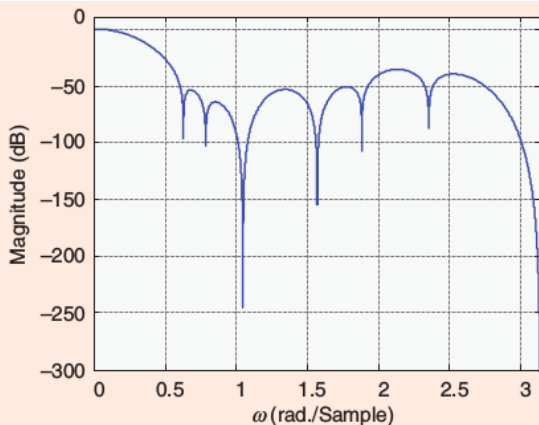
(from Improving FIR Filters by Using Cascade Techniques Tips & Tricks  
David Shiung; Ya-Yin Yang; Chu-Sing Yang

IEEE Signal Processing Magazine Year: 2016, Volume: 33, Issue: 3)



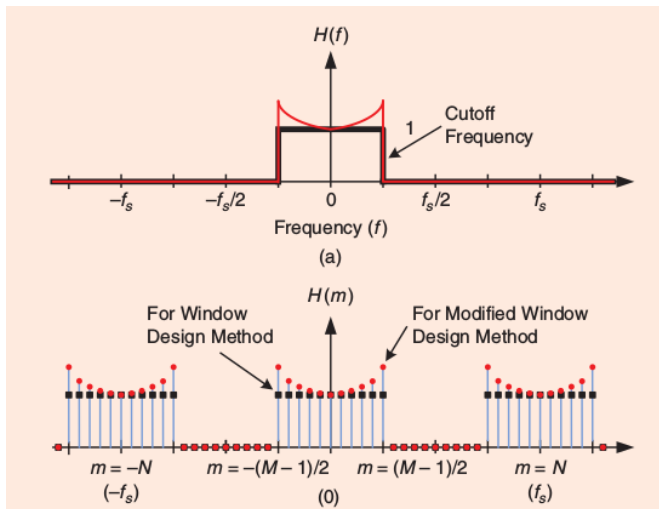
The magnitude frequency responses of CCFs for  $K = 1, 2, 3, 4$ .

## LP filter with tricks

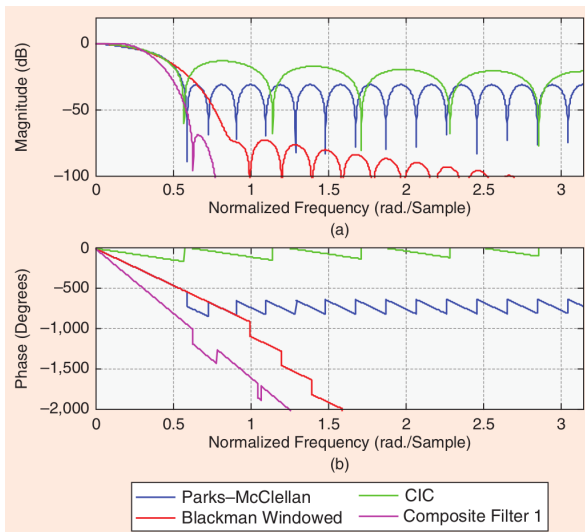


The magnitude frequency response of a cascade of CCFs. The transfer function is  $(1 + z^{-1})^2(1 + z^{-2})^2(1 + z^{-3})^3(1 + z^{-4})(1 + z^{-5})$ .

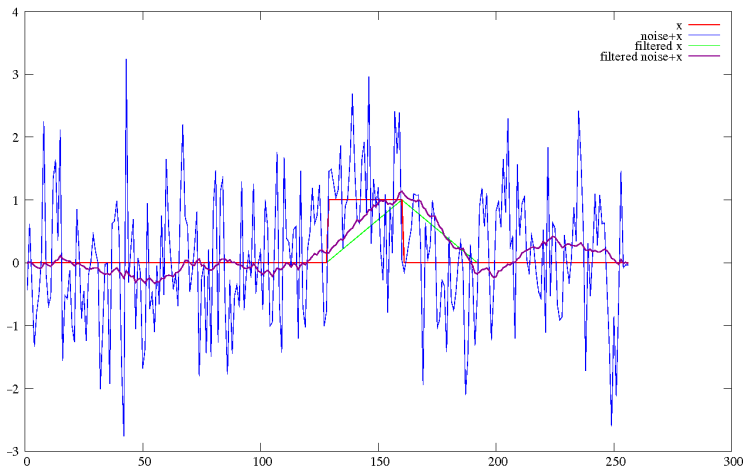
## LP filter with tricks



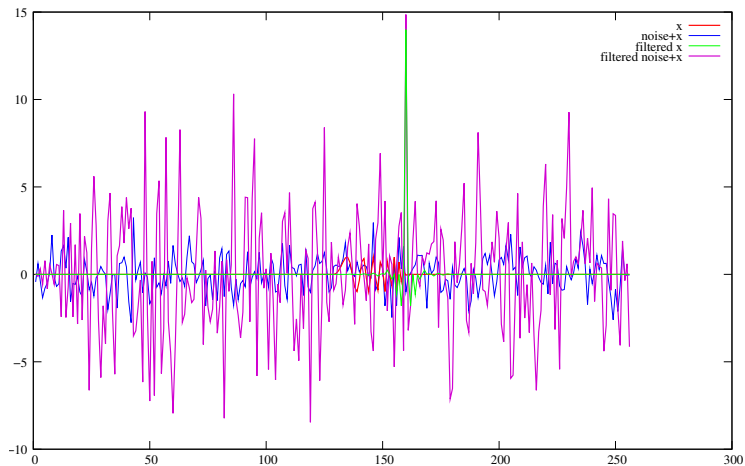
## LP filter with tricks



## Matched filter - square impulse



## Matched filter - LMF impulse





# Other advanced subjects

- ▶ Weak signal detection w/MF
- ▶ Pulse compression w/MF
- ▶ Adaptive filters